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The Biology of FAD-Associated Tuna: Temporal Dynamics of Association and Feeding Ecology

Kim Holland, Dean Grubbs, David Itano, Brittany Graham, and Laurent Dagorn

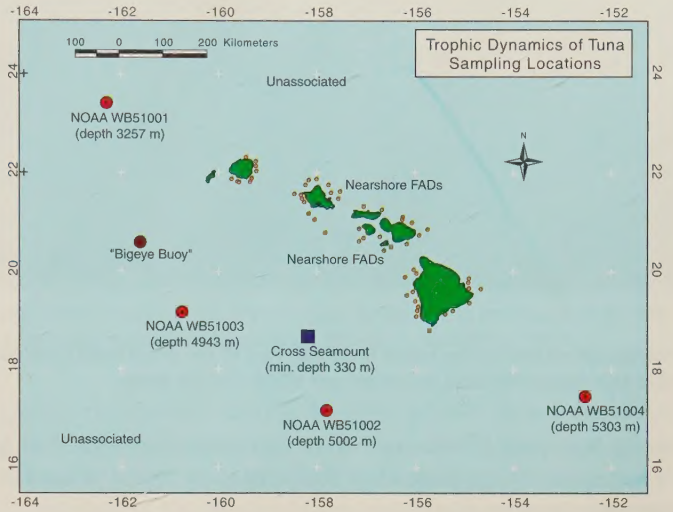
Introduction

Most tropical tunas captured by commercial and recreational fishers worldwide are "associated." Sometimes this association is with natural structures such as seamounts or reefs or drifting logs, but increasingly these associations are with man-made fish aggregating devices—FADS. In fact, some researchers estimate that over 50%, by weight, of the total tuna catch in the Indian and Pacific Oceans is now taken near FADs. FAD deployment has increased steadily over the last 25 years and has become rampant over the last decade. Until recently, there has been very little consideration of the ecological impact of the practice. Understanding the amount of time that tuna spend in association with FADs and the trophic dynamics of FAD-associated tuna are critical to evaluating the impact of FADs on tuna distribution, their vulnerability to fishing gear, and the impact of FADs on their overall well being.

To address these issues, we have embarked on a comprehensive investigation of the trophic ecology of FAD-associated tuna in Hawaiian waters and have combined this with experiments using sonic telemetry to observe the movements of tuna within the network of anchored FADs in Hawaiian waters. This report presents preliminary results and data analysis of these interrelated projects. Data presented here were obtained using three techniques: gut content analyses, isotope ratio analyses, and sonic telemetry. The telemetry involves placing coded acoustic pingers in fish captured at FADs and detecting the implanted pingers with data logging hydrophones attached to the mooring lines of the FADs.

Gut Content Analyses

Gut content data indicate that there are distinct and consistent differences in prey consumed by yellowfin tuna and bigeye tuna when they are found in association with man-made FADs. Whether they are associated with deep (>2,500 m) offshore FADs or FADs located in shallower (<1,500 m) water and within 15 nm of shore, yellowfin show greater feeding success than bigeye. These differences may be due to the fact that yellowfin consume epipelagic prey, whereas bigeye feed more frequently on deeper, mesopelagic species. Apparently, the shallower depths adopted by bigeye when they associate with FADs disrupt their deeper feeding behavior, whereas the shallower feeding yellowfin are less affected



Tuna aggregation sites in Hawaiian waters: Cross Seamount, nearshore FADs deployed by the state of Hawaii, and NOAA weather buoys which act as offshore FADs.

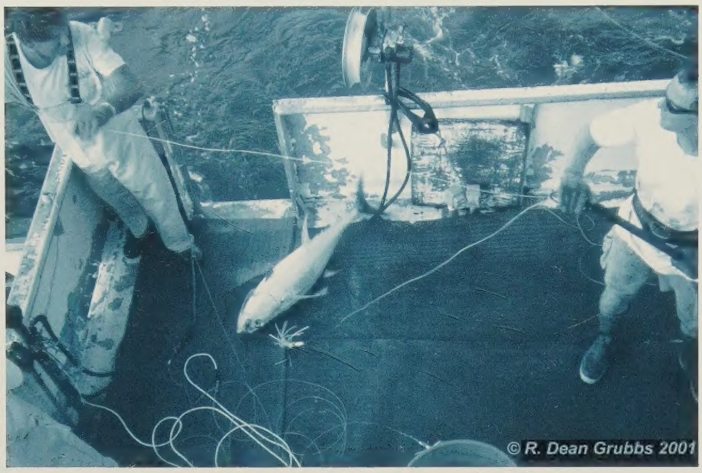
by their association with FADs. On the offshore FADs, larger yellowfin feed more successfully than smaller specimens, but small yellowfin seem to feed well when they are found in association with nearshore FADs—primarily by feeding on stomatopod larvae and oplophorid shrimp.

Conversely, bigeye feed very well when associated with Cross Seamount. Again, this may be due to the fact that, in general, bigeye feed on deeper organisms, and certain seamounts seem to provide an enriched source of these mesopelagic prey. In all locations,

(continued on page 2)

CONTENTS

The Biology of FAD-Associated Tuna: Temporal Dynamics of Association and Feeding Ecology 1
After the Storm—HMS Area Closures: Do the Predictions Match the Results? 3
Pacific Tuna Treaty on Track for 2004 Entry into Force; New Commission Taking Shape 5
Upcoming Events 5
Report of the International Workshop on Current Status and New Directions for Studying Schooling and Aggregation Behavior of Pelagic Fish 7



Fishing aboard the fishing vessel Double D, part of the commercial handline fleet that fishes the Cross Seamount and NOAA weather buoys.

the dietary overlap between bigeye and yellowfin of all sizes is minimal, but it is greatest when the animals are found in association with the seamount.

Isotope Ratio Analyses

In complementary experiments, carbon and nitrogen isotope analyses of yellowfin and bigeye tuna caught at FADs indicate that a shift in feeding ecology may be occurring at sizes between 40 and 50 cm (FL). Although not necessarily correlated with FAD related behavior, a shift in diet may be occurring when fish reach about 45 cm FL. Also, there appears to be a difference in the isotope signatures of similarly sized yellowfin and bigeye. That is, in sizes > 50 cm, bigeye appear to occupy a higher trophic stratum than yellowfin of similar size. Further testing will be necessary to confirm these interpretations.

Sonic Telemetry

The duration of FAD-associated behavior and inter-FAD movements are being determined by placing acoustic pingers in FAD-associated fish. Data loggers attached to the mooring lines of all 13 FADs surrounding the island of Oahu monitor their positions. These data are still being collected, and detailed analysis has not yet begun. However, a preliminary examination of the data appears to confirm results of earlier tag-and-recapture and sonic tracking experiments. Namely, that there are two consistent types of behavior exhibited by FAD-associated fish—some stay in almost constant contact with the FAD for prolonged periods of time (sometimes several weeks), and others stay for very short visits (a few minutes) before departing. One objective of future analyses will be to determine if these behavioral differences persist in the same individuals when they move from one FAD to another or whether the same fish can exhibit both types of behavior.

An offshore FAD-NOAA Weather Buoy 51002 located approximately 200 km south of the Big Island.

S-buoy—a nearshore FAD deployed off the leeward coast of Oahu.

All three facets of this research are still in data collection mode, but these early results indicate that a significant advance in our understanding of the biology of FAD-associated tuna should be forthcoming.

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After the Storm—HMS Area Closures: Do the Predictions Match the Results?

David Kerstetter

Recent developments in the Hawaiian pelagic longline fishery have highlighted the role of closed areas in pelagic fishery management. These measures are frequently being implemented both domestically and internationally for both the target species and bycatch. In the United States, NMFS is required to evaluate the impacts of proposed regulations on the affected fisheries. This PFRP-funded project compares the predicted results of two pelagic longline closures—one Atlantic and one Pacific—with those conditions existing after their implementation.

Closed time and area management regimes are now used in several locations in U.S. waters to manage highly migratory species (HMS) and longline fisheries interactions, but relatively little attention has been given to the empirical effects of post-implementation displaced fishing effort on the longline fishery fleets or to catch rates. Previous analysis by the NMFS HMS Management Division identified probable effort changes resulting from the imposition of closed areas in the Gulf of Mexico and Atlantic Ocean designed to protect swordfish nursery waters and to reduce dead discards. In addition, modeling by the NMFS Honolulu Laboratory of the court-mandated closure to protect sea turtle populations evaluated potential impacts of closed times and areas due to sea turtle take-reduction guidelines. This paper compares previously predicted effort changes with actual results from these closed areas.

The post-implementation analysis of these closed areas is rarely done formally. This may be a function of the "brushfire" nature of life within the agency or may simply reflect a lack of personnel. The criteria for the relative success of these time and area closures are overall by-catch rates, the economic effects of the closures on the fleets, and changes in total catches. This analysis contrasts these results with those predicted prior to the closure. The measures met with differing success, although even "successful results" may not be reflective of the closure itself.

Case Studies

Florida Closure

The development of the pelagic longline fleet off the east coast of Florida occurred in two stages: the development of a small coastal fishery in the 1960s, followed by a rapid expansion of the fleet in the late 1970s. This fleet increased swordfish landings dramatically through the 1980s, although during this same time, the average size also began dropping, and in 1990, the International Commission for the Conservation of Atlantic Tunas (ICCAT) established a minimum size requirement. Under this measure, however, regulatory discards of juvenile swordfish kept increasing.

The Former Swordfish Longline Fleet in Port St. Lucie, Florida. Many of these older, short-range vessels are no longer in the fishery as a result of the NMFS closed area management measures. (Photo: D. Kerstetter, 2000.)

During the development of the 1999 Atlantic Tunas, Swordfish, and Sharks Fishery Management Plan, NMFS proposed several alternative closed areas to reduce this regulatory bycatch.

Analyses of the effects of these possible closed areas were conducted prior to implementation, using displacement and non-displacement assumptions regarding the activity of the fleet fishing in these areas. Under this modeling, fishing effort was expected to either disappear entirely (no displacement) or redistribute to the remaining open areas proportionally to the effort levels prior to the closure (displacement). The modeling predicted a reduction in juvenile swordfish catch between 27.7% and 38.0%, and a reduction in adult landings by 10.8% to 23.7% (NMFS, 1999). Changes in effort by the fleet were not predicted per se, although given that most of the fleet consisted of vessels under 50 ft LOA and that the fishing grounds were relatively close to shore, a decline in effort was thought likely. Based on the changes in landings, revenues were estimated to decline by 9.3% to 24.0%.

The actual results suggest that the closure predictions were rather optimistic. Based on 2001 data, there was an 86.7% reduction in the number of deployed hooks by the fleet, and over 40 vessels left the fishery. This reduction in effort resulted in a 93.7% reduction in juvenile bycatch and a 53.1% decrease in swordfish landings, as well as a 53.8% reduction in ex-vessel revenue (NMFS, 2003a). It is noteworthy that swordfish imports to the United States continued to increase during this time (NMFS, 2003b).

Western Central Pacific Closure

The biological status of several turtle species in the Pacific Ocean is threatened by a variety of activities. Three of these species are listed as endangered or threatened under the Endangered Species Act (ESA). One of the most documented interactions of turtles with human activities in the United States is with the pelagic longline fleet, most of which is based in Honolulu, Hawaii.

(continued on page 4)

Following a suit alleging non-compliance with National Environmental Policy Act guidelines by not preparing an adequate environmental assessment regarding these turtle species under ESA protections, a court order in 1999 (CMC et al. v. NMFS, Civ. No. 99-00152 DAE) required NMFS to prepare a comprehensive environmental impact statement (EIS) on this fishery. This EIS examined the fishery and proposed alternative management measures to reduce the level of sea turtle interactions.

Analyses of the effects of the closure option that was eventually selected were based on GAM modeling efforts by Kobayashi and Polovina (2000). Described more fully in their paper, this modeling used "static" and "dynamic" assumptions of fishing effort in concert with environmental and fishery data to produce estimates of fishing effort disruption. Under the chosen management option, levels of sea turtle interactions were predicted to decline by 85%, with a predicted 22.6% reduction in the number of vessels. Fleet-wide, this was expected to result in a decline in ex-vessel revenues between 10% and 45%.

The actual results were closer to what had been predicted than the predicted results in Florida. There was a 12% reduction in the number of vessels, but a 12.1% increase in the number of sets and a 42% increase in the number of set hooks (Ito and Machado, 2001; NMFS, 2003c). Although the fleet-wide effort may have increased, observer reports indicate a reduction in turtle interactions of 69.5% from pre-closure conditions. Even more interesting were the landings results, which for swordfish declined by 83.9%, but for bigeye tuna increased by 82.8%, reflecting the change in targeting by the fleet. Ex-vessel revenues have actually increased approximately 10.1% for the fleet.

For The Future?

Both closures were based on biological needs, whether the need to reduce the bycatch of juvenile swordfish for ICCAT management standards or sea turtles to comply with the protective provisions of the ESA. However, the case can be made rather easily that they have both been successful—the rates of bycatch have been reduced under the management measures. However, both fleets have also been structurally changed, likely permanently.

The two approaches to predicting the effects of these closures were well thought-out yet did not accurately predict actual results. Efforts to model the behavior of fishing vessels remain in progress, and much work has been done to better describe the economic conditions of the fleets so as to better understand the decision-making processes of the vessel owners and operators. For example, the recent work to characterize the Hawaiian longline fleet by O'Malley and Pooley (2003) suggested that many vessels were only marginally profitable even before the closure and that several operators were already considering leaving the fishery. In the Atlantic fishery, the NMFS HMS Management Division is currently planning to update the similar work by Porter et al. (2001).

Several barriers to successful pelagic closures remain. On a population level, highly migratory species, including by-catch, benefit most from collective international cooperation. The United States consistently promotes bycatch reduction efforts in international fora and maintaining international agreements remains a clear NMFS priority (NMFS, 2002). In some cases, measures may already be in place, but what remains notably lacking is the political will to enforce them, especially in the Atlantic distant-water fisheries. Domestic statutes such as the ESA also limit the range of alternative actions by the agency. However, under selected conditions and clearly defined goals, pelagic time-area closures may be effective tools for fishery management.

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Pacific Tuna Treaty on Track for 2004 Entry into Force; New Commission Taking Shape

John Sibert

Nadi, Fiji, 5–9 May 2003

The Multilateral High-Level Conference (MHLC) concluded on 5 September 2000 with the signing of the Convention on the Conservation and Management of Highly Migratory Fish Stocks in Western and Central Pacific. Simultaneously with the signing of the Convention, the MHLC adopted a resolution creating a Preparatory Conference for the Establishment of the Commission for the Conservation and Management of Highly Migratory Fish Stocks in Western and Central Pacific. The primary task of the Preparatory Conference is to lay the administrative foundation for the Commission and, if necessary, to recommend conservation and management measures during the period between the signing of the Convention and its entry into force.

The fourth session of the Preparatory Conference met in Nadi, Fiji, 5–9 May, 2003, and was attended by representatives from Australia, Canada, Cook Islands, European Community, Federated States of Micronesia, Fiji, France, French Polynesia, Indonesia, Japan, Kiribati, Republic of Korea, Marshall Islands, New Caledonia, New Zealand, Niue, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Chinese Taipei, Tonga, Tuvalu, United States of America, Vanuatu, and Wallis and Futuna. China was unable to send a delegation because of the SARS epidemic but was represented on the opening day by the Ambassador of the Peoples Republic of China to Suva. Observers from the South Pacific Forum Fisheries Agency (FFA), the South Pacific Regional Environment Programme (SPREP), the Forum Secretariat, the Food and Agriculture Organization of the United Nations (FAO), the Inter-American Tropical Tuna Organization (IATTC), the Secretariat of the Pacific Community (SPC), and the University of the South Pacific (USP) also attended the conference. The USP observers included a group of students studying marine affairs.

The Convention will enter into force after ratification by three states north of 20° north latitude and seven states south of 20° north latitude. Alternatively, if within three years of the adoption of the Convention (that is, by September 2003) it is ratified by 13 states, the Convention will enter into force six months after the thirteenth ratification. Seven states south of 20° north have now ratified the Convention. Federated States of Marshall Islands, Fiji, Republic of the Marshal Islands, Papua New Guinea, and Samoa have deposited instruments of ratification, and the Republic of Kiribati announced during the conference that their government has ratified the Convention. Although there were no official announcements, several other states made it clear during the conference that their governments were close to ratification. If so, the Convention could enter into force in 2004.

Upcoming Events

16th Meeting of the Standing Committee on Tuna and Billfish
Australia
July 9–16, 2003

Second Meeting of the Scientific Coordinating Group of Preparatory Conference for the Establishment of the Commission on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean
Mooloolaba, Australia
July 17–19, 2003

Pelagic Fisheries Research Program Principal Investigators Workshop
Imin Conference Center, University of Hawai'i at Manoa, Honolulu, Hawai'i
December 9–11, 2003

The official work of the PrepCon is conducted by its three working groups: WG-I: Organizational structure, budget, and financial contributions (chaired by Lucy Bogari, PNG); WG-II: Scientific structure and provision of scientific advice (chaired by John Kalish, Australia); and WG-III: Monitoring, control, and surveillance (chaired by Bill Gibbons-Fly, USA). All working groups except WG-II, which did not meet formally, made substantial progress at PrepCon4.

Working Group I: Organizational Structure, Budget, and Financial Contributions

Much of the work of WG-I was technical, involving the finer points of administrative and financial rules and procedures. Although there was substantial progress on most of the outstanding issues with respect to the draft rules and procedures, opinions diverged widely on rules proposed by Japan for the Northern Committee. Further discussion of this issue was deferred until the next session of the PrepCon. The draft financial regulations received first reading. The most difficult issue to resolve will be the formula for financial contributions to the Commission. There was general agreement that there will be a three-tiered approach to financial contributions, comprising a base fee, a national wealth component, and a variable fee based on the amount of production. Participants disagreed on the specific proportions of the budget from each tier (10%, 20%, 70% or 20%, 40%, 40%) and on the method of computing the national wealth component (per capita GNP or World Bank shares).

The issue of participation by territories was raised but did not

(continued on page 6)

receive much discussion. The governments of France and New Zealand have taken steps to give full competence over Exclusive Economic Zone resources to their territories, but delegates to the PrepCon felt that the issue needed more study and would be considered in detail at the next session of the conference.

The Convention calls for creation of a special fund to facilitate effective participation of small island developing states. It is understood that this fund would cover not only the costs of participation in Commission meetings but would also be used to promote human resource development in small island states. The FFA countries strongly favor financing this fund from assessed contributions. Other parties, notably the United States, favor voluntary contributions. This issue is proving contentious—on one hand, participation by all parties in Commission activities is essential if it is to operate effectively. On the other hand, the purpose of the Convention is fisheries management and not economic and social development.

Working Group II: Scientific Structure and Provision of Interim Scientific Advice

WG-II did not meet formally during PrepCon4, but a brief informal meeting was convened at the last minute. It was announced that Chris O'Brien, from New Zealand, has been seconded to the PrepCon Interim Secretariat as science coordinator, to assist with the heavy workload of WG-II. The WG-II session was largely informational, with the Chair providing a useful summary of progress to date and outlining the remaining work of WG-II and the Science Coordinating Group (SCG).

The WG-II chair requested intersessional input in two areas: (a) comments on the paper entitled "Review of Ecosystem-Bycatch Issues for the Western and Central Pacific" (WCPFC/PrepCon/WP.9), presented to PrepCon3 in Manila, and (b) a short, annotated list of current research projects relevant to the PrepCon.

The second meeting of the SCG is planned for July 17–19, in Mooloolaba, Australia. Papua New Guinea and Japan announced that they would provide funds in support of participation in SCG2 by small island developing states. The tasks for SCG2 include articulation of long-term data needs of the Commission; updating the status of stocks of skipjack, yellowfin, bigeye, and South Pacific albacore; and development of research priorities for the Commission.

WG-II will meet formally at the next session of the PrepCon and is expected to consider the report of SCG2, the structure for scientific functions, the role of existing regional organizations in obtaining the best available scientific and other fisheries-related information, special requirements of developing states in relation to data requirements and technical capacity, and approaches to ecosystem and bycatch issues. Clearly, PrepCon 5 will be a critical stage for determining how the Commission will conduct its scientific activities and whether these activities will be truly independent and immune from manipulation by Commission members.

Working Group III: Monitoring, Control, and Surveillance

The problems of boarding and inspection occupied most of the attention of WG-III at PrepCon 4. At issue are whether, and under what circumstances, does the Convention call for fishing vessels be stopped, boarded, and inspected. Can vessels be routinely stopped on the high seas by foreign vessels? For how long can fishing operations be interrupted before inspection becomes harassment? Participants disagreed on these issues, but the discussions were considered fruitful and will form the basis of a revised paper to be prepared by the WG-III chair.

Working Group III also discussed the development of the Commission observer program. Participants agreed on several general principles, but the details of the observer program need further development. In particular, Working Group III must consult with WG-II to clarify the role and duties of observers. WG-III is expected to have a full agenda at PrepCon 5.

Other Matters

The United States tabled a strongly worded statement on the issue of capacity. The statement noted that yellowfin and bigeye stocks are near their limits of exploitation, that catches of skipjack have been so high in recent years that the price of skipjack has fallen to levels that make it difficult to fish profitably, and that repeated resolutions to exercise "reasonable restraint" with respect to the growth of fishing effort have been ignored. Japan has also expressed concern over capacity and illegal, unlicensed, and unregulated (IUU) fishing, and Korea called for what amounts to a moratorium on the growth of purse seine and large-scale longline fleets. Taiwan, however, notes that the skipjack resource can sustain higher levels of exploitation and that it intends to increase its purse seine fleet. FFA member states are also concerned with this issue and are currently exploring alternative means to limit capacity. The PrepCon endorsed the proposal by FFA members that WG-II and SCG develop a report that will include assessment of (a) the status of major highly migratory stocks in the Convention Area, (b) the impact of FADs on juvenile stocks, (c) gaps in currant data, and (d) the implications for sustainability. This report will probably be produced at SCG2, in July.

An operational definition of "excess capacity" was not offered at PrepCon 4, but the term was loosely interpreted to mean too many fishing vessels operating in the Convention Area. While some restricted the term to purse seine vessels, others interpreted it more broadly, to include longline vessels of all sizes.

Delegates to PrepCon 4 were conscious of the possibility of entry into force in 2004. Therefore, the general tenor of the session was constructive, and much of the discussion focused on resolution of technical issues relating to rules, regulations and finance. The next session of the Preparatory Conference will take place in Rarotonga, Cook Islands, 29 September through 3 October 2003. All of the working papers and working group reports of from the Preparatory Conference (papers from all sessions) can be obtained from the WCPFC web site http://www.ocean-affairs.com.

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Report of the International Workshop on Current Status and New Directions for Studying Schooling and Aggregation Behavior of Pelagic Fish

Laurent Dagorn and Kim Holland

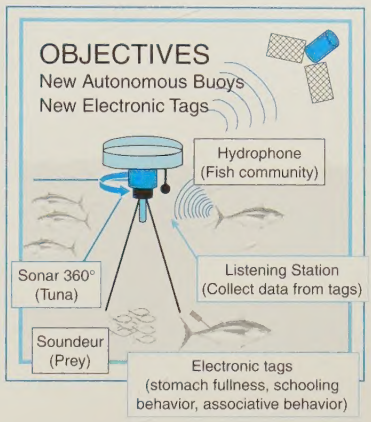
Dr. Laurent Dagorn (Institut de Recherche pour le Développement, France) and Dr. Kim Holland (University of Hawaii) organized this workshop. It took place 7–9 October 2003, at the Hawaii Institute of Marine Biology, Coconut Island, Oahu, Hawaii and was sponsored by the Pelagic Fisheries Research Program (PFRP), Dr. John Sibert, Program Manager.

The overall objective of the workshop was to examine how we could improve our knowledge of the basic mechanisms of the collective behavior of pelagic fish. One of the main objectives was to bring together scientists who work in various fields of schooling and aggregation behavior of pelagic fish but who often do not have opportunities to meet to compare results and discuss new theories and interpretations.

Twenty-two participants from the USA, Europe, Japan, and South America, attended the 3-day workshop. The workshop comprised two sessions, Aggregative Behavior, with 6 talks, and Schooling Behavior, with 11 talks.

Many pelagic fish are known to school and/or aggregate at particular sites such as seamounts or floating objects. Many fisheries use this behavioral characteristic to increase their catches, and schooling fish are among the most heavily exploited species in the world's oceans. Association with specific objects such as floating objects (Fish Aggregating Devices, or FADs) or seamounts by tropical tuna has considerably modified the exploitation techniques used by the tuna fishing industry and by artisanal fisheries. Despite their practical importance, our knowledge of the characteristics and dynamics of these schools and aggregations, as well as their biological origins, is very poor. Because we know so little about this behavior, stock assessment and fishery management rarely consider schools and aggregations, even though they represent key components of the system.

Schooling behavior of fish has been studied mainly through observations on captive fish in aquaria and on very small groups. However, pelagic schools and aggregations usually comprise thousands of individuals, and the relationships between the behavior of small captive schools and the behavior of large schools in the ocean (and therefore to fishery management) are not easily understood. Ethologists working on captive animals rarely communicate with fishery biologists and fishery managers. Likewise, there is little communication between scientists working on small pelagic fish and those working on large pelagic fish, and these researchers have seldom met to compare findings.



Studying the schooling and aggregation behavior of pelagic fish is difficult because (a) pelagic fish are often difficult to maintain in captivity, and tanks are usually not big enough for developing experiments on the collective behavior of these fish; and (b) observing pelagic fish in the ocean is always a challenge. It is also noteworthy that scientists working on small pelagic fish and those working on large pelagic fish do not use the same tools to observe their animals. The former use acoustics (echosounders and sonars) to detect and sometimes track schools, but it is very difficult for them to study the behavior of individuals within schools. In contrast, because it is usually quite difficult to observe the behavior of a school of large pelagic fish, those working with these animals normally deal with individual behavior (fine- and large-scale tracking of individuals) but not with their collective behavior. Schooling behavior is therefore almost never included in movement or population models, even though it is likely that the movements of a schooling individual are not those of a solitary animal. Moreover, studying the relationships between different species occurring in mixed schools or aggregations is a major issue for an ecosystem-based management of pelagic fisheries.

The literature contains different definitions of the terms aggregation and school. The purpose of the workshop was not to decide which are best, but it was necessary to choose one definition of each term to prevent semantic problems during the workshop. For the purposes of the workshop, aggregations were considered to be assemblages of units in one place. During the workshop, we considered only active aggregations, in which animals are attracted to a source (a FAD, for instance). Schools were defined as fish in polarized and synchronized swimming.

It is obvious that observing pelagic fish in their environment is a great challenge. Each tool allows observation of only a small portion of real life. Most workshop participants agreed on the importance of the development of interdisciplinary tools. Combinations of instruments (sonars, electronic tags, hydrophones) and combinations of disciplines (physiology, behavior, genetics, statistical modeling, simulations) should be encouraged, as well as exchanges of information between teams with different expertise. There was a consensus for determining testable predictions. The first step will be to define metrics that can be measured in vitro and in situ, and also be used for simulations, whatever the studied species.

There is also a clear need for work on the sensory biology of pelagic fish, from small pelagic fish (e.g., sardines) to large ones,

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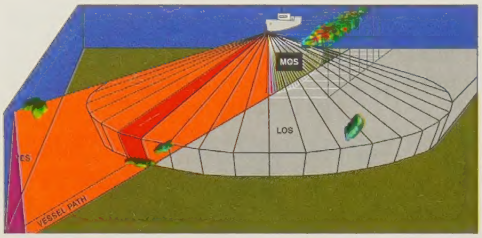

Combination of different sonars for better observations of schooling behavior (lateral sonar for 3D images of schools, vertical sounder for density estimates, long-range sonar for remote observations of school movements and positions)

such as tunas. Such physiological studies have been more or less neglected during recent years. It is now obvious, however, that greater knowledge in areas such as hearing ability, visual acuity, and olfactory sensitivity will be important in both designing new observational techniques (for instance, new generations of "ecology tags") and in interpreting the schooling phenomena observed in different species.

One of the main conclusions reached at the workshop was that inter-species research is an important tool in understanding aggregative and schooling behavior. Fish of different species exhibit different collective behaviors: Does each species have specific collective rules for schooling and aggregating, or do different species simply refine a set of universal rules? By studying different pelagic schooling species, it will be easier to understand these collective behaviors and their role in population dynamics.

Workshop participants were enthusiastic about the meeting, and several propositions were advanced to keep the group alive:

- Organization of an international symposium on collective behavior of pelagic fish
- Publication of a book on this subject
- Organization of a network on collective behavior of pelagic fish

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